Spacecraft Hazard Avoidance Utilizing Structured Light

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Contents

Introduction

- Free-flying micro-inspector spacecraft is being designed for a host-vehicle inspection to improve its safety
- Spacecraft includes a hazard avoidance sensor
- Structured light was selected due to low mass and cost

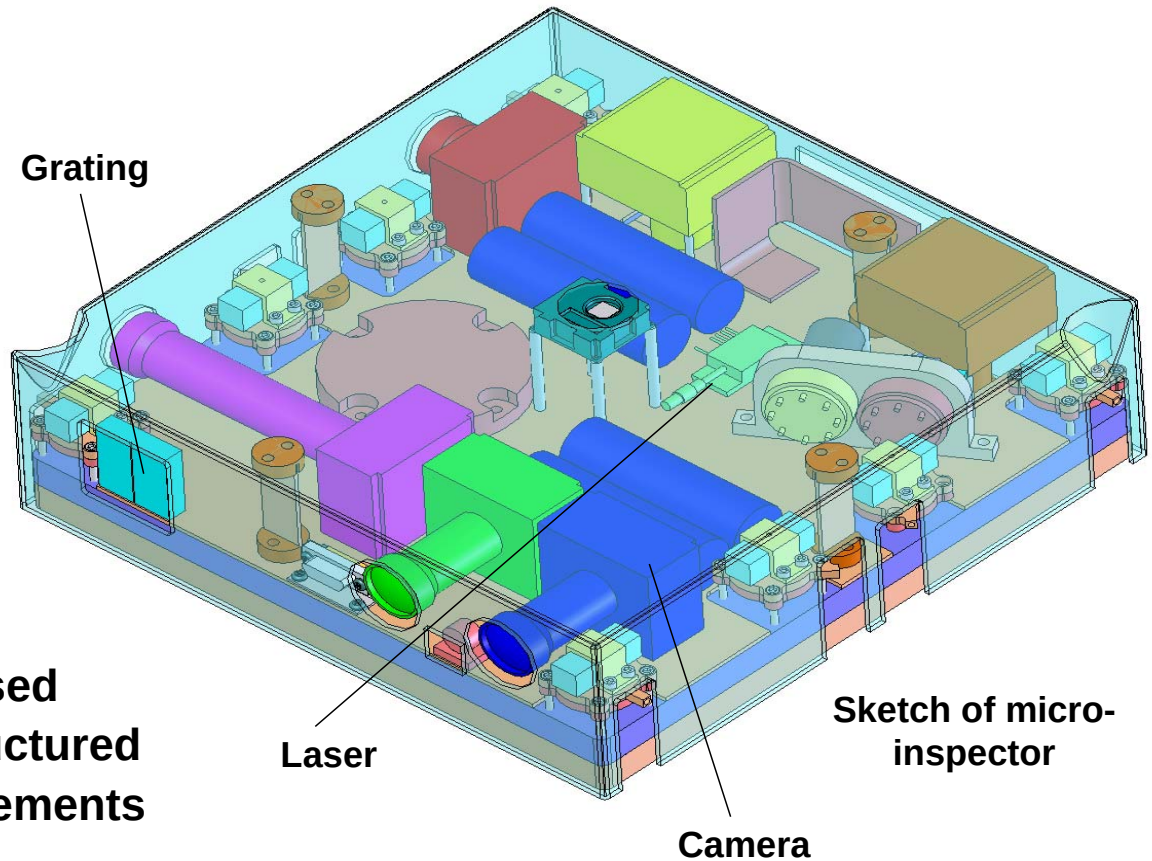
Approach	Structured light	Stereo vision	Laser radar	Microwave radar
Mass (kg)	< 1	< 1	6	~ 30
Power (W)	A few	A few	< 40	~ 200
Max range	Tens of meters	Tens of meters	2.5 km	Kilometer range
Night operation	Yes	No	Yes	Yes
Computations (MIPS)	< 10	> 100	< 1	>> 100

Mission and Spacecraft

- Potential host missions and mission scenario include:
  - Crew Exploration Vehicle
  - Lunar descent
  - Earth reentry prior to descent
  - Monitoring of critical in-space assemblies or deployments

- Micro-Inspector is a fully functional autonomous spacecraft

- Micro-Inspector employs the laser-based hazard avoidance sensor utilizing structured light to provide relative range measurements to the host



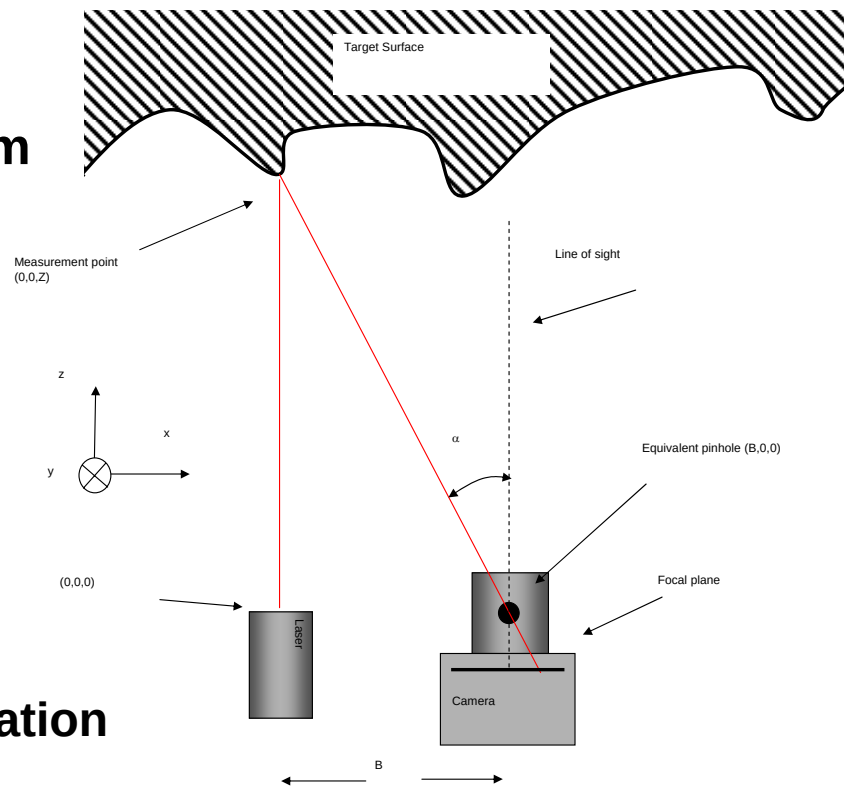
Sketch of micro-inspector

- It contains cameras used for visual inspection, range detection and as star trackers

Description and Theory

- Structured light is a method of remote sensing of 3- dimensional structure of the proximity utilizing a laser, a holographic grating, and a regular APS camera

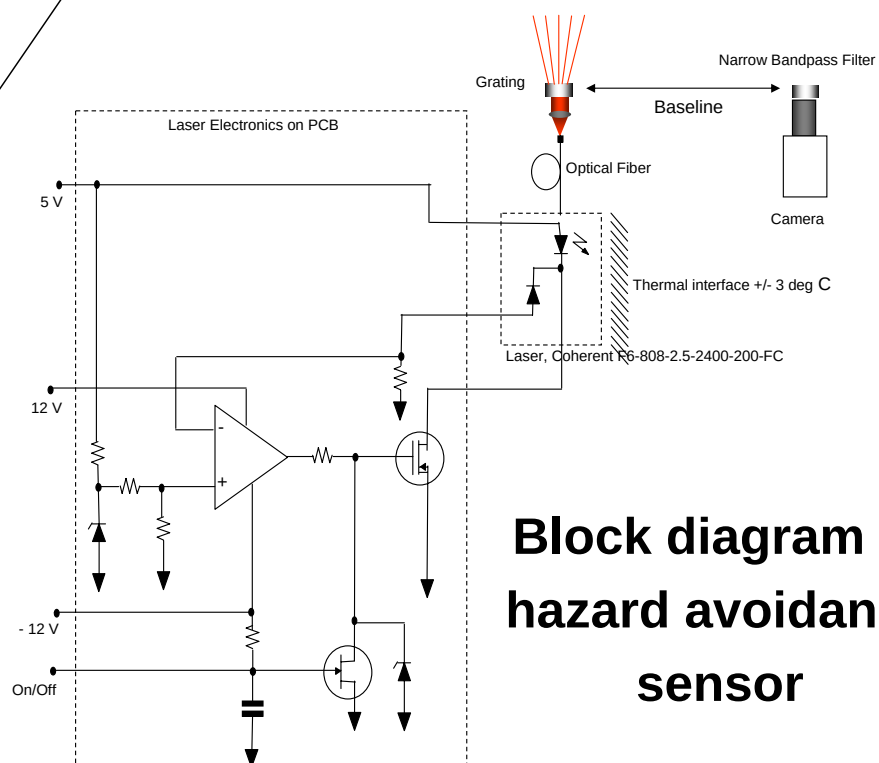
- Scenario for an ideal single laser beam triangulation is shown



- Six parameters describe geometry of non-idealized system:
  - separation between laser and camera
  - elevation and azimuth angle that laser beam is offset along z-axis
  - 3x3 rotation matrix describing camera rotation

Model Implementation

- Camera with a band pass filter mounted on the lens
- Laser diode, collimating lens and diffraction grating
- Laser drive electronics



Block diagram of hazard avoidance sensor

Model Realization (Cont.)

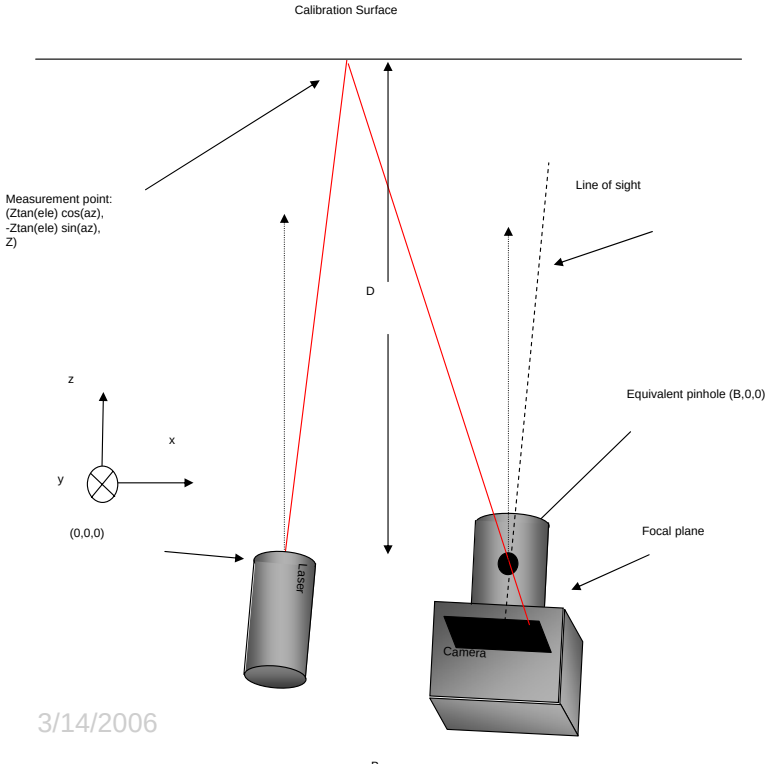
- **The laser beam is split into 400 different beams by a holographic grating to form a regular spaced grid of laser beams that are projected into the FOV of camera**

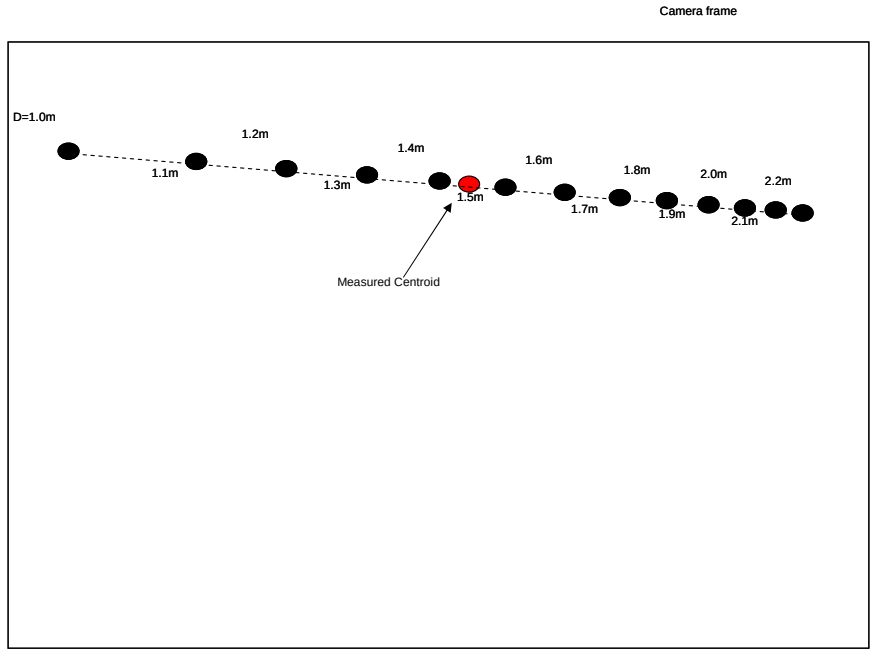
- **The laser source and the camera are separated forming the base of a triangle**

- **The distance to all beam spots with the host are calculated based on triangulation**

Calibration Routine

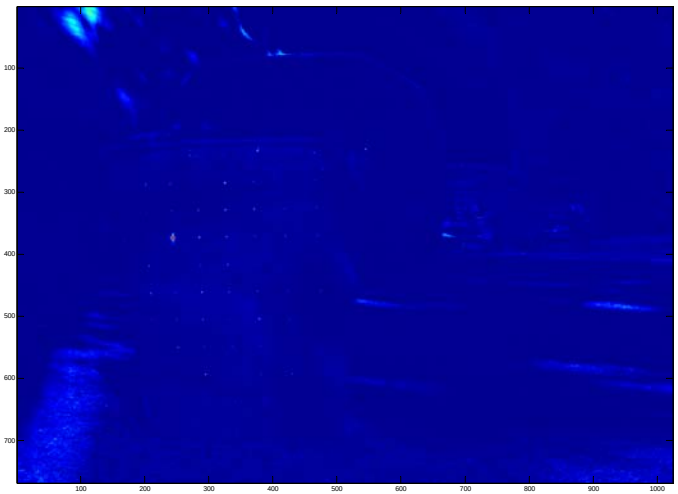
- An image is required and the centroid of the spot is calculated
- The system is then moved to a new distance and a new image (centroid) is obtained
- The procedure is repeated up to the maximum distance required by the system
- After calibration, the system is pointed at unknown (with a red spot centroid) distance which is being estimated from the calibration curve





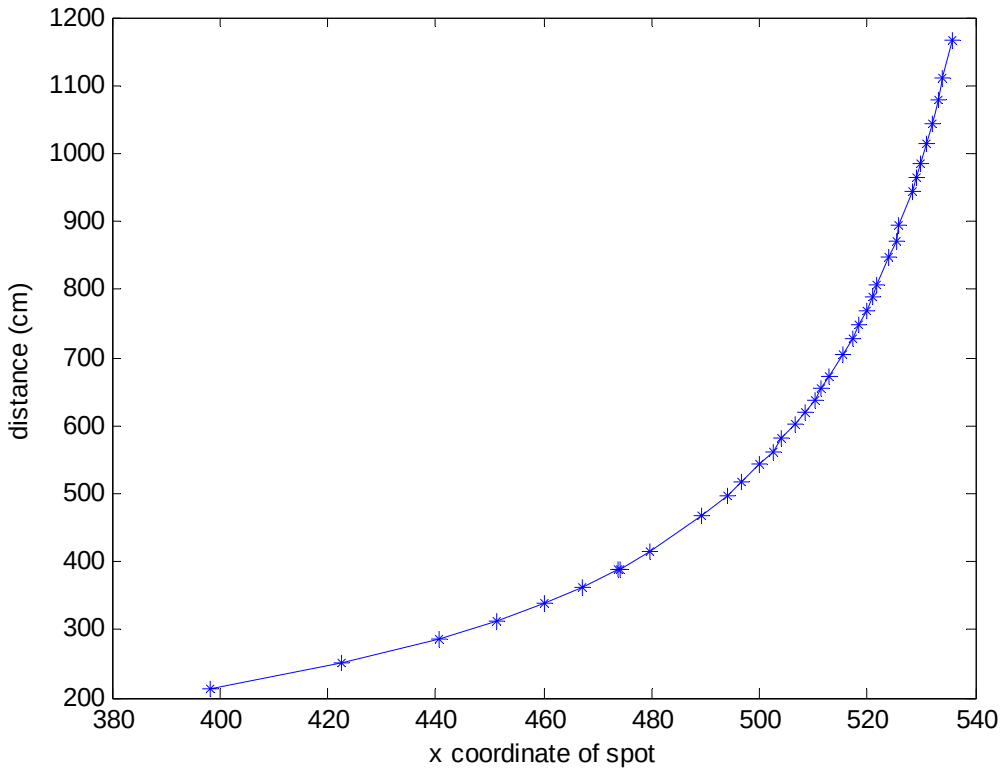
Testing and Results

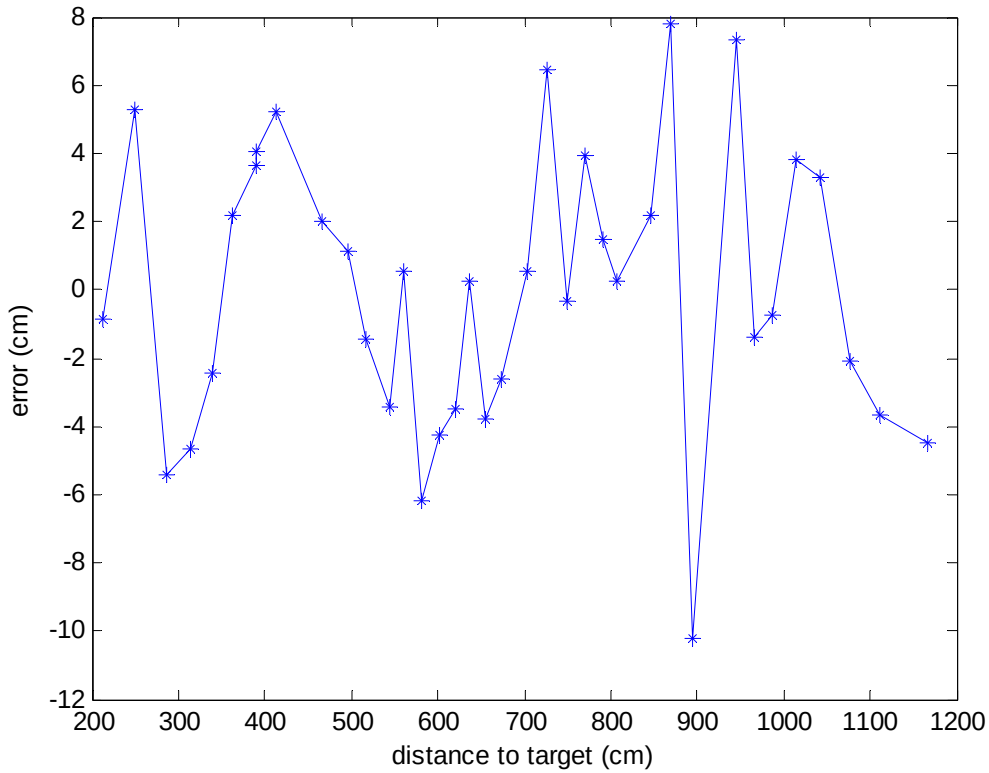
- An image of laser illuminated surface with sun presence
- The difference of two images (with a laser “on” & “off”) in false colors
- Identified centroids of spots created with 632 nm 20 mW breadboard laser



Testing and Results (Cont.)

- Accuracy measurements of the hazard avoidance sensor
- Total station measurements as a function of x-coord. of particular spot's centroid
- System uncertainty measurements vs. distance (right)





Summary

- **Laboratory breadboard model has been built utilizing a commercial camera and an eye safe laser**
- **The system will be able to operate at distances up to 12 m and the accuracy of the system is demonstrated to be 4 cm (rms) at those distances**
- **Further testing is underway**